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ABSTRACT

The factor structure of a new co-normed cognitive and achievement battery for children, the Differential Ability Scales (DAS) was investigated. The DAS was factor analyzed in conjunction with the Peabody Picture Vocabulary Test-Revised (PPVT-R), and the composite score of the Iowa Test of Basic Skills (ITBS). Subjects were 56 six- to eight-year-old children in regular classes. Two exploratory principal axis factor analyses with varimax rotation were done (one with and one without the four DAS "diagnostic" subtests). The exploratory analyses revealed a factor structure fairly consistent with the composite structure of the DAS. The DAS verbal subtests loaded with the PPVT-R and the DAS achievement tests loaded with the ITBS. Three cognitive factors and one achievement factor were normed, but they strayed somewhat from the DAS composite structure. A confirmatory factor analysis showed that the theoretical structure of the DAS provided a good fit to the data. These analyses lend support to the test author's interpretation of the DAS. Four , tables present data from the analyses. (Author)

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Joint Exploratory and Confirmatory Factor Analysis of the DAS, PPVT-R and ITBS

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Abstract

The factor structure of a new conormed cognitive and achievement battery for children, the Differential Ability Scales (DAS) was investigated. The DAS was factor analyzed in conjunction with the Peabody Picture Vocabulary Test-Revised (PPVT-R), and the composite score of the Iowa Test of Basic Skills (ITBS). Subjects were 56 six to eight year old children in regular classes. Two exploratory principle axis factor analyses with varimax rotation were done (one with and one without the four DAS "diagnostic" subtests). The exploratory analyses revealed a factor structure fairly consistent with the composite structure of the DAS. The DAS verbal subtests loaded with the PPVT-R and the DAS achievement tests loaded with the ITBS. Three cognitive factors and one achievement factor were formed, but they strayed somewhat from the DAS composite structure. A confirmatory factor analysis showed that the the theoretical structure of the DAS provided a good fit to the data. These analyses lend support to the test author's interpretation of the DAS.

Joint Exploratory and Confirmatory Factor Analysis of the DAS, PPVT-R and ITBS

The Differential Ability Scales (Elliott, 1990a; DAS) is an individually administered conormed cognitive ability and achievement battery. The DAS was normed on 3,475 children, ages 2 years 6 months through 17 years. The subtests vary in the ages for which they are appropriate. Most involve tasks that are associated with other popular measures of intelligence, such as giving word definitions, reproducing block designs, and drawing figures. A few are unique to the DAS (e.g., Speed of Information Processing), or are administered in novel ways (e.g., Recall of Digits).

The school age portion of the DAS (ages 6 through 17 years 11 months) consists of six "core" cognitive subtests, three achievement subtests and three additional "diagnostic" subtests. An additional fourth diagnostic subtest is highly reliable up to age 8, beyond which it is reliable for only average or below average ability children. The DAS provides three cognitive composites (Verbal Ability, Nonverbal Reasoning Ability and Spatial Ability), each of which consist of two related core subtests. The six subtests that make up these three composites are combined into a

broader composite, reflecting an underlying general factor. This broad composite is termed the General Conceptual Ability (GCA) score, and is meant to be a more tightly defined measure of g than is available from other tests of cognitive abilities.

The GCA composite score of the DAS correlates highly with the broad composites of other frequently used individually administered tests of cognitive abilities (Elliot, 1990b), such as the Wechsler Intelligence Scale for Children-Revised (Wechsler, 1974) and the Stanford-Binet Intelligence Scale: Fourth Edition (Thorndike, Hagen & Sattler, 1986). However, the DAS reflects an underlying theoretical structure that is different from other cognitive batteries. In addition to providing slightly different clusters the DAS does not include its three memory subtests (Recall of Digits, Recall of Objects and Recognition of Pictures) or the Speed of Information Processing subtest into its broad composite. These four subtests are termed diagnostic, and are meant to be interpreted individually.

The DAS diagnostic subtests are considered by the test author to be relatively independent of the other cognitive subtests and less related to general reasoning ability. The DAS diagnostic subtests do not

contribute to any composite, as they would purportedly render the composite less interpretable.

In order to adequately compare and contrast the constructs underlying the DAS with other well validated instruments of ability and achievement, two frequently used criterion measures were selected. The Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981; PPVT-R) was chosen as a verbal measure, while the Iowa Test of Basic Skills (Riverside, 1986; ITBS) was used as a well validated measure of group achievement.

Wright (1987) submitted that studies of this nature be carried out on normal (non-referred) children. Samples referred for learning difficulties may present more discrepant ability-achievement patterns than non-referred samples. Such a sample could artificially reduce the likelihood that ability and achievement measures may load on common factors, thus obscuring structural relationships underlying the battery. Therefore, in determining the overall factor structure of a test it is important to use a normal sample.

Keith (1990) recommended that to better understand the factor structure of the DAS it should be factor analyzed with other measures. Indeed, this type of research provides discriminant and convergent validity

information for a test (Campbell & Fiske, 1959). Along these lines Schmitt and Stults (1986) have recommended that exploratory factor analysis be used to discover or generate adequate hypotheses regarding underlying factor structure. Confirmatory factor analysis can then more appropriately be used to confirm or disconfirm the existence of the factor structure across convergent and discriminant measures.

Method

Subjects

The DAS and PPVT-R were administered to 56 first and third grade regular education students (28 from each grade). All subjects attended the same elementary school in a Midwestern urban school district. There were similar numbers of girls (n = 27) and boys (n = 29) in the study. The age range was 6 to 10 years, with 7 years (n = 24) and 9 years (n = 20) being the modal ages. Administration of the DAS and the PPVT-R was counterbalanced for order of test presentation and for form of the PPVT-R (L and M). The most recent composite score on the ITBS (Form H) Levels 6 and 8 for the first and third grade children respectively were obtained for each child.

Instrument

For the school-age DAS, the six subtest GCA score

consists of the six core cognitive subtests, chosen for their high g loadings and for an underlying similarity in measuring conceptual ability and reasoning. These subtests are grouped into three clusters, two subtests to a cluster, which are described below. The clusters, the GCA, and the achievement subtests are reported as age-based standard scores with means of 100 and standard deviations of 15. The cognitive subtests are reported as age-based T- scores with means of 50 and standard deviations of 10. All the following subtests and clusters span at least the ages of 6 through 17 except where otherwise noted.

Verbal Ability Cluster

Word Definitions. Orally presented words are defined.

Similarities. Three words are presented. The examinee must tell how the three are similar.

Nonverbal Reasoning Ability Cluster

Matrices. A child must choose from among four or six patterns the pattern which correctly completes the missing cell in a matrix of four or nine cells.

Sequential and Quantitative Reasoning. Initial items consist of simple abstract figures with one part of the series missing. The child is asked to draw the missing figure in the appropriate place. Later items

consist of three sets of number pairs, with the second number missing from the third pair. The child must either speak or write the missing number.

Spatial Ability Cluster

Recall of Designs. A non-pictorial line drawing is presented to the child for five seconds. It is then removed and the child must draw the design from memory.

Pattern Construction. Initial items require that designs in a booklet be copied using yellow and black crepe squares, with either side of the square being entirely yellow or black. Later items involve copying designs from a booklet using three dimensional squares which have alternate black, yellow, and black and yellow sides. The latter sides are black and yellow divided either vertically or horizontally. The patterns to copy begin with two blocks and progress to nine blocks.

Diagnostic Subtests

These additional cognitive subtests include tests of memory and speed of information processing. These subtests do not contribute to the GCA score, and are less predictive of achievement than are the core subtests (Elliott, 1990b).

Recall of Digits. The child repeats a sequence of digits presented orally at the rate of two digits per

second.

Recall of Objects. For each of the three immediate-recall trials, the child looks at a card with 20 objects pictured for a set length of time. The card is removed and the child recalls as many objects as possible.

Recognition of Pictures. Typically used up to age 8, this test can be administered through age 17 for average and low ability children. The child is shown a picture of one or more objects for a set length of time. A second picture is then displayed from which the child must identify the previously viewed object(s). The second picture contains additional distractor items.

Speed of Information Processing. The child must scan across rows on a page to mark the circle with the most boxes or the highest number for each row. The child's score is the amount of time it takes to complete each item (page), assuming two errors or less are made on an item.

Achievement subtests

The DAS achievement subtests were conormed with the cognitive battery. The achievement subtests are meant to be academic screening tests rather than comprehensive tests of achievement.

Word Reading. A word list is read aloud.

Basic Number Skills. Early items involve number recognition and couting skills, while later items are calculated on a worksheet and require standard arithmetic operations and advanced numerical calculations using whole numbers, decimals, fractions and percentages. The final few items are word problems.

Spelling. The child writes words that are dictated by the examiner in a word-sentence-word sequence.

Procedures

The DAS was factor analyzed with the PPVT-R and ITBS to examine the internal structure of the DAS. An initial exploratory principle axis factor (PAF) analysis with varimax rotation was done using all the DAS subtests in conjunction with the PPVT-R and ITBS (15 variables in all). Because cognitive factors tend to correlate, a factor solution allowing the factors to correlated was deemed most realistic. Therefore the oblique varimax rotation was used. Initial communality estimates were squared multiple correlations.

A second PAF analysis was run without the DAS diagnostic subtests, as the high levels of reliable specificity of these subtests would suggest that they would either tend to form their own factor or not

specifically load on any one retained factor. Either result would be problematic for factor interpretation. In addition, by reducing the factor matrix to 11 variables the sample size of 56 is more in line with Gorsuch's (1974) recommended minimum of 5 subjects per variable. Therefore, the four diagnostic subtests were deleted from a second PAF analysis.

To verify the exploratory findings, the LISREL VII computer program (Joreskog & Sorbom, 1989) was used to run a maximum likelihood confirmatory factor analysis on the combined covariance matrix of the DAS core and achievement subtests, the PPVT-R and the ITBS. The covariance matrix is considered to be more appropriate than the correlation matrix for this purpose because the same sample is used to standardize the variables and calculate covariances (Loehlin, 1987). Eleven variables were included in the model. The model was consistent with the DAS composite structure as suggested by the previous exploratory analyses. The six DAS core subtests were specified to load on three cognitive factors. In addition, the PPVT-R was specified to load on the Verbal Ability factor. The three DAS achievement measures were specified to load with the ITBS on an achievement factor. All factors were allowed to correlate.

Results

Means, standard deviations and ranges for the 15 variables are included in Table 1. It can be seen that

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Insert Table 1 about here

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the sample was generally above average on most variables. This is not surprising in that the sample specifically excluded children receiving special education.

In the first exploratory analysis four factors had eigenvalues greater than one and were retained. The scree plot of the eigenvalues also showed four factors to sufficiently represent the data. As a group the four retained factors accounted for 51% of the total variance. Significant factor loadings were determined to be .40 and above (Stevens, 1987). The factor loadings and correlations are displayed in Table 2.

Insert Table 2 about here

The first factor appears to be an amalgam of the four achievement variables, the two variables which make up the DAS Nonverbal Reasoning Ability cluster, and the PPVT-R. It is apparently a g factor minus

expressive verbal ability. The second factor is composed of the two variables that make up the DAS Verbal Ability cluster, as well as the PPVT-R and the ITBS. This factor appears to be best characterized as verbal comprehension. The third factor is made up of the three DAS achievement subtests, and two DAS diagnostic subtests, Recall of Digits and Speed of Information Processing. Rote memory and numbers are reflected in this factor, although it is somewhat difficult to interpret. The fourth factor was characterized by high loadings from the two DAS Spatial Ability cluster subtests and a diagnostic subtest, Recognition of Pictures. Clearly, the fourth factor is a spatial factor. Recall of Objects did not load on any factor, and apparently measures a construct independent of the other four.

The four diagnostic subtests were dropped from the second analysis. The 11 variables yielded four factors. The criterion for factor retention was relaxed somewhat for this analysis as eigenvalues are dependent on the number of variables. Since the number of variables was reduced by about 25% the criterion for inclusion was reduced commensurately. A visual inspection of the scree plot showed four factors to be above the scree. As a group the four retained factors

accounted for 59% of the total variance. Significant factor loadings were determined to be .40 and above (Stevens, 1987). The factor loadings and correlations are displayed in Table 3.

Insert Table 3 about here

The first factor is again distinguished by the high loadings of the four achievement variables, along with one of the variables which makes up the DAS Nonverbal Reasoning Ability cluster, Matrices (the other variable in this cluster, Sequential and Quantitative Reasoning, is just slightly below the .40 cutoff). This factor is apparently a g factor minus verbal ability. The second factor is again composed of the two variables that make up the DAS Verbal Ability cluster, as well as the PPVT-R and the ITBS. This factor again appears to be best characterized as verbal comprehension. The third factor is a more clearly defined factor, made up of the two subtests in the DAS Nonverbal Reasoning Ability cluster. The fourth factor is characterized solely by high loadings from the two DAS Spatial Ability cluster subtests. Clearly, the fourth factor is the DAS spatial factor.

The second analysis suggested that the composite

structure of the DAS may adequately portray the factor structure. When submitted to a Confirmatory Factor Analysis the goodness-of-fit statistics showed that the underlying theoretical structure of the DAS seemed to provide a good fit to the data. The goodness-of-fit statistics are displayed in Table 4.

Insert Table 4 about here

It should be noted that the Chi-square, df, goodness-of-fit and adjusted goodness-of-fit indices are based on analysis of the covariance matrix, whereas the root mean square residual and factor loadings are based on analysis of the correlation matrix (Keith, 1990). The probability that the model does not fit the data is .241, indicating that the model does provide a good fit to the data. The two Goodness-of-fit statistics indicate a good fit, as these indices are on a scale of zero to one with one indicating a perfect fit. The root mean square residual indicates that the average difference in correlations between the original correlation matrix and the one predicted by the model was .073. Kerlinger (1986) cites anything less than .10 as providing a reasonable fit. In addition, all factor loadings are above .5, indicating strong

loadings on each factor.

The phi matrix of factor intercorrelations shows that the achievement factor correlates the highest with the Nonverbal Reasoning Ability subtests. This was seen in the exploratory analysis with the consistent tendency of the Nonverbal Reasoning subtests to load on a factor with the achievement tests. The largest positive standardized residual was 3.1, between the PPVT-R and ITBS. This indicates that the model would provide a better fit if these two variables were allowed to correlate together more, such as allowing the PPVT-R to also load on the achievement factor, or allowing the ITBS to also load on the Verbal Ability factor.

Discussion

All three analyses revealed a factor structure fairly consistent with the structure of the DAS. In the first analysis there were three cognitive factors (Verbal Ability, Spatial Ability, and a "Rote Memory + DAS Achievement" factor). The PPVT-R and the DAS Nonverbal Reasoning Ability subtests loaded with the achievement tests on an achievement factor. The PPVT-R and ITBS also loaded with the Verbal Ability subtests, showing Word Definitions and Similarities to be somewhat related to achievement as well. The Spatial

factor consisted of the two DAS Spatial Ability subtests and one DAS diagnostic subtest that measures visual recognition memory. The Rote Memory + DAS achievement factor was difficult to interpret and contained two of the DAS diagnostic subtests. One other diagnostic subtest, Recall of Objects, did not load on any of the four factors. This supported Elliott's (1990b) contention that the diagnostic subtests are relatively independent and should not be forced into a composite. Forcing these subtests into a composite renders the composite less tightly focused and interpretable.

The second PAF analysis, done without the DAS diagnostic subtests, more clearly showed the DAS factor structure. Again, three cognitive factors were formed, but this time were more consistent with the DAS composite structure. A Verbal Ability, Nonverbal Reasoning Ability and Spatial Ability factor clearly emerged. The PPVT-R and the ITBS again loaded on the Verbal Ability factor, while one DAS cognitive subtest (Matrices) loaded with the achievement factor.

The tendency of the ITBS to load on the Verbal factor is not surprising in that it contains a good deal of listening comprehension and vocabulary type items. Also, the tendency for the PPVT-R and ITBS to

load together is expected for the same reason.

The second PAF analysis suggested that the DAS model as evidenced in the framework of composite scores was tenable. The Confirmatory analysis seemed to provide a confirmation to the proposed factor structure. An analysis of the goodness-of-fit statistics showed that the underlying theoretical structure of the DAS provided a good fit to the data obtained in our sample. Overall, the analyses appeared to yield support for the interpretation of three separate but correlated cognitive factors underlying the DAS, as proposed by the test author.

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Table 1.

Mean, Standard Deviation and Range of DAS, PPVT-R and ITBS Variables

Variable	Mean	SD	Range
Word Definitions	51.1	11.6	25 - 80
Similarities	56.4	11.9	33 - 80
Matrices	53.8	9.0	36 - 80
Sequential & Quant.	55.0	9.1	34 - 70
Recall of Designs	53.7	10.4	30 - 79
Pattern Construction	48.9	9.7	28 - 74
Recall of Digits	50.3	9.0	30 - 67
Recall of Objects	50.1	8.4	24 - 69
Recognition of Pict.	48.9	9.3	33 - 73
Speed of Information	49.4	11.2	20 - 80
Word Reading	104.9	12.0	81 - 134
Basic Number Skills	102.0	14.1	64 - 133
Spelling	105.3	11.4	82 - 128
PPVT-R Std. Score	106.1	12.5	76 - 133
ITBS National %ile	80.2	18.2	21 - 99

Table 2.

Rotated PAF Factor Matrix with Loadings for All 15 Variables on Four Extracted Factors

Variable	Factors: 1	2	3	4
Word Definitions	.09	.65	.08	.16
Similarities	.06	.64	-.13	.18
Matrices	.70	.09	.07	.12
Sequential & Quant.	.64	.32	.16	.21
Recall of Designs	.36	.00	-.11	.65
Pattern Construction	.26	.09	.21	.55
Recall of Digits	.09	.01	.64	.03
Recall of Objects	.10	.10	.12	.35
Recognition of Pict.	-.07	.26	.12	.47
Speed of Information	.14	-.34	.52	.23
Word Reading	.60	.21	.43	.28
Basic Number Skills	.44	.16	.63	.21
Spelling	.65	.01	.49	.20
PPVT-R	.43	.67	-.03	.02
ITBS	.50	.48	.23	.21

Factor Correlations: 1 and 2: .20

1 and 3: .34

1 and 4: .31

2 and 3: .26

2 and 4: .03

3 and 4: .31

Table 3.

Rotated PAF Factor Matrix with Loadings for 11 Variables on Four Extracted Factors

Variable Factors:	1	2	3	4
Word Definitions	.13	.64	-.02	.11
Similarities	-.08	.64	.13	.10
Matrices	.44	.09	.63	.07
Sequential & Quant.	.38	.39	.57	.18
Recall of Designs	.14	.10	.36	.42
Pattern Construction	.30	.12	.05	.81
Word Reading	.72	.23	.24	.26
Basic Number Skills	.63	.14	.21	.22
Spelling	.85	.03	.23	.15
PPVT-R	.29	.72	.19	-.05
ITBS	.47	.51	.22	.23

Factor Correlations: 1 and 2: .28
1 and 3: .36
1 and 4: .49
2 and 3: .26
2 and 4: .31
3 and 4: .31

Table 4.

Confirmatory Factor Analysis for 11 Variables: Four Factor Model

Variable	Factors: 1	2	3	4
Word Definitions		.61		
Similarities		.54		
Matrices			.70	
Sequential & Quant.			.82	
Recall of Designs				.58
Pattern Construction				.73
Word Reading	.85			
Basic Number Skills	.72			
Spelling	.81			
PPVT-R		.85		
ITBS	.69			

Chi-Square with 38 df = 43.74 (p = .241)

Goodness of Fit Index = 0.87

Adjusted Goodness of Fit Index = 0.77

Root Mean Square Residual = .073

Phi (Factor Correlations): 1 and 2: .54

1 and 3: .81

1 and 4: .72

2 and 3: .60

2 and 4: .30

3 and 4: .60